

Uninfected Elm Wood as a Source of the Bark Beetle
(*Scolytus multistriatus* Marsham)
Carrying the Dutch Elm Disease Pathogen

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THE WOODPILE, A BREEDING PLACE OF THE BARK BEETLE

Beetles emerging from the elm wood in the woodpile probably inoculated the adjacent elm tree

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UNINFECTED ELM WOOD AS A SOURCE OF THE BARK BEETLE (*SCOLYTUS MULTISTRIATUS* MARSHAM) CARRYING THE DUTCH ELM DISEASE PATHOGEN

DONALD L. COLLINS, K. G. PARKER, AND HENRY DIETRICH¹

It has been known for several years that bark beetles of the family Scolytidae may carry the Dutch elm disease pathogen, *Ceratostomella ulmi* (Schwarz) Buisman, presumably, for the most part, in the form of spores. Fransen (1939) gives Marchal² credit for having been the first to suggest that elm bark beetles were concerned in the transmission of the Dutch elm disease organism. Wollenweber and Stapp (1928), having seen *C. ulmi* in the pupal cells of *Scolytus scolytus* Fabricius, also suggested the relationship between these bark beetles and the fungus. In Europe this relationship has been confirmed by Fransen (1931) and by Fransen and Buisman (1935), not only for *S. scolytus* but also for *Scolytus multistriatus* Marsham. In the United States transmission of the fungus by *S. multistriatus* from infected wood to healthy elms was described by Middleton, Buchanan, May, and Walter in 1935. *S. multistriatus* is now generally considered to be the most effective agent in the transmission of this fungus in the United States.

In order to determine what percentage of beetles in the field were actually carrying inoculum, many specimens of *Scolytus multistriatus* were collected and cultured. They were taken at felled, healthy trees as they alighted for entry, at dead trees which had died from causes other than the Dutch elm disease, at broken branches of uninfected trees, and at piles of freshly cut, healthy elm logs set up to attract them. The percentages of "positive" beetles (beetles from which *Ceratostomella ulmi* was obtained) varied widely from year to year and from locality to locality. In 1935, in the Bronx, New York City, which was at that time in an area of heavy disease incidence, 15 per cent of the 411 specimens of *S. multistriatus* that were collected and cultured were positive. In 1936, from Bronx, Westchester, and Rockland Counties, 7.6 per cent of 688 specimens were positive. In 1937, in Westchester County, 2.9 per cent of 3618 specimens were positive. In 1938, of 225 specimens collected in Yonkers (Westchester County) only 2, or 0.9 per cent, were positive; while in 1939, at Tarrytown, 1 of 9 specimens, and at Hyde Park (Dutchess County), 7 of 122 specimens (percentages of 11.10 and 5.74 respectively) were positive.

When beetles in the disease area carry inoculum to the extent indicated, their origin or source becomes a question of importance. It has already been noted that specimens emerging from wood from diseased trees can carry the spores of the fungus. An idea of the number of beetles carrying the fungus at the time they emerged from such material was gained from

¹Professor P. A. Readio initiated some of the experiments described in this paper and developed certain techniques used in handling the beetles. Dr. W. H. Rankin, supervisor of Dutch Elm Disease Control of the New York State Department of Agriculture and Markets, and members of his staff, cooperated to the fullest extent, especially in locating beetle material and in facilitating the field observations on diseased trees. Acknowledgment is also due the Boyce Thompson Institute for Plant Research, where the Cornell University Laboratory for Dutch Elm Disease Investigations is located, for cooperation and assistance. Other members of the laboratory staff who had a considerable share in the investigations reported here were Seth Pope, L. L. Pechuman, and L. J. Tyler.

²Marchal, E. Rapport sur les résultats des recherches effectuées à la Station de Phyt. de l'État à Gembloux, sur la maladie de l'orme. Soc. Centr. Forest. Belgique. Bul. 35: 162-164. 1927.

several experiments. Wood from diseased elms which contained colonies of *Scolytus multistriatus* was brought into the laboratory and beetles which emerged from it were cultured. For this purpose, wood which had considerable discoloration in the outermost growth ring, or wood in which coremia of the fungus were found in the pupal cells of the beetles, was chosen. The standard method adopted for treating such wood was to cut it into 20-inch lengths, coat both ends and any other points where wood was exposed with paraffin to retard drying, and place it in small cages. If the beetles were in the pupal stage the wood was cut up and caged immediately after collection. If the beetles had entered only a short time before collection, the wood was usually left in longer pieces. Just before emergence was expected, the wood was cut up and caged. A few inches at each end of the log, where drying was most rapid, were usually discarded. The percentages of emerging beetles carrying spores out of the wood in the several cages varied from 0 to 100. The fungus infestation of the beetles was influenced by the condition of the wood, the extent of the fungus invasion at the time of collection, and the temperature and moisture conditions under which the wood was kept.

Culture records of the progeny of uninfested beetles which were allowed to enter diseased wood in the laboratory or greenhouse also indicated that constancy could not be expected in the numbers of spore-bearing beetles emerging from diseased wood. After entry of the beetles, special treatments, such as dipping the logs in water at regular intervals, boring holes in the ends and sides and keeping them filled with water, and the maintenance of high humidity in the storage chambers, produced results which sometimes varied with the treatments and sometimes independently of them. The highest percentage of positive beetles in the experiments carried out in 1935-36 was 44, with an average of less than 6 in the remaining cages. In 1936-37, the highest percentage of positive beetles from any one cage was 81.8. In these experiments, wood from 4 different sources produced beetles which averaged 41 per cent positive of the 1820 cultured from all cages. Similar variations undoubtedly occur as a result of analogous but uncontrolled and often unknown conditions in the field.

C. W. Collins and his associates (1936) found that beetles could obtain inoculum by feeding in twig crotches of diseased trees, and could transfer it to the brood galleries which they subsequently made. At the Cornell University laboratory in Yonkers, beetles were disinfested externally and allowed to feed on badly wilted, diseased trees. Of the 121 beetles which were alive when removed after feeding two or three days, 15, or 12.4 per cent, were shown by culturing to have acquired inoculum. Cultures of beetles from the same lot, which had not fed on diseased trees, produced no growth of *Ceratostomella ulmi*.

C. W. Collins and his associates also found that beetles emerging from diseased wood could transfer the disease organism to their brood galleries, and reported a number of instances in the field where the fungus was growing in galleries of beetles which had entered uninfected³ wood. Fransen (1931) recorded coremia growing in pupal cells of *Scolytus scolytus*, and observed that beetles could bring the fungus into the bark by introducing it

³The term *uninfected* is used in this paper to refer to wood or trees in which, as far as could be determined, there had been no infection by *Ceratostomella ulmi* prior to the death or cutting of the tree or branch involved.

into their egg tunnels. The authors of this bulletin have often found dead trees and woodpiles near diseased trees, with evidence that *Scolytus multistriatus* had emerged in great numbers, and in several instances with coremia of *Ceratostomella ulmi* not only in the maternal galleries but also in the pupal cells.

EXPERIMENTS

Observations such as these led to the suspicion that woodpiles and other breeding-wood originating in uninfested trees might have given rise to some of the fungus-infested beetles found in the field. In laboratory experiments, beetles were disinfested to render them less likely to contaminate their galleries with unwanted bacteria and fungi and were then allowed to walk for several hours over coremia of *Ceratostomella ulmi* growing in pure culture on elm twigs. At the end of this period, the most active beetles were selected and placed in cages containing healthy elm logs cut into 20-inch lengths. For experimental purposes the cages were kept under widely different conditions of temperature and humidity. Holes were bored in some of the logs and filled with water at regular intervals. The moisture in others was maintained or increased by regular wetting or dipping. The progeny of the beetles placed in the cages were cultured. The wood in 32 of the 39 cages produced beetles infested with *C. ulmi*. The percentages of positive beetles varied from 0 to 74.4. The total number of beetles cultured was 3028, of which 1106, or 36.5 per cent, carried *C. ulmi*. These figures compared favorably with those obtained from cages of diseased wood, as may be seen by reference to data already given.

It was thus shown that under suitable conditions fungus-infested beetles entering healthy wood give rise to spore-bearing progeny, and also that the percentages of these progeny bearing *Ceratostomella ulmi* are comparable to the percentages of spore-bearing beetles which emerge from wood from diseased trees. Observations and field experiments as described below have confirmed this conclusion, and have indicated that uninfested wood may constitute an important factor in the spread of the Dutch elm disease. The pertinent data are assembled under five headings: (1) trap logs, (2) collection stations, (3) naturally occurring uninfested "beetle-wood" (broken limbs, dead trees, and dead parts of living trees containing *Scolytus multistriatus*), (4) woodpiles, (5) relation of beetle-infested uninfested wood to diseased trees.

TRAP LOGS

Each year, beginning in 1935, trap logs of recently cut, healthy American elm have been placed at several locations in and around the disease area for the purpose of attracting elm bark beetles. The logs were 3 to 4 feet in length and usually from 3 to 8 inches in diameter. Ordinarily they were exposed by leaning them against a stone wall, fence, or similar support in a sunny or partly sunny situation. They were placed in position within a day or two after cutting and brought in for examination at varying intervals. Fresh logs were put out each time exposed logs were collected. The regular periods of exposure were 2 weeks, 4 weeks, and 6 weeks. Logs were examined or caged the day after they were collected.

In 1935, a trap-log station was set up in each of three localities: Armonk, Westchester County; Yonkers, Westchester County; and Pelham Bay

Park, the Bronx, New York City. The stations, while in an area of general disease incidence, were not located with reference to specific diseased trees. The Yonkers station was located in the Boyce Thompson Arboretum (called BTA in some of the tables, as distinguished from the Boyce Thompson Farm, BTF, where a station was established later for other purposes). The logs at Armonk and at Yonkers were heavily infested with *Hylurgopinus rufipes* Eich., almost to the complete exclusion of *Scolytus multistriatus*. Only one gallery of the latter species was found and examined at each of these two stations. *S. multistriatus* galleries were very numerous in the logs exposed at Pelham Bay Park. When the bark was removed, the galleries were examined for coremia of *Ceratostomella ulmi*. Coremia were not found in the gallery from Armonk, but were present in the single gallery from Yonkers, and were found in 75, or 4.6 per cent, of the 1605 galleries examined from Pelham Bay Park. Living beetles were found in some of the newer galleries, and a number of them were removed and cultured. The newer galleries were not examined unless they appeared to be old enough to have allowed time for coremia to develop. The total count of galleries, therefore, may include many which were too new to have produced coremia. Of 146 beetles taken from new galleries at Pelham Bay Park in 1935, 9, or 6.1 per cent, were positive for *C. ulmi*. The data mentioned, together with figures supplementing the remarks which follow, are given in table 1.

In 1936, no galleries of *Scolytus multistriatus* were found in the Armonk logs, and only 5 galleries, which were negative, were found at the Yonkers station. At Pelham Bay Park, the beetles were again numerous, and of 730 galleries examined, 21, or 2.9 per cent, contained coremia of *Ceratostomella ulmi*. Of the 219 beetles which were taken from the maternal tunnels, 60, or 27.4 per cent, were positive. The lower half of one of the Pelham Bay Park logs was placed in a cage to await the emergence of the progeny of the beetles that had entered it in the field. In the upper half of this log, coremia had been found in 8 of about 27 galleries examined from different parts of the inner-bark surface. The percentage of galleries containing coremia was approximately the same as for the total number of galleries examined at the same time from the other logs. The log had been cut on June 29, exposed on June 30, brought in on August 25, and examined and caged immediately. Between September 1 and September 24, beetles were emerging and 53 specimens of *S. multistriatus* were collected. Of these, 48 were cultured and 30, or 62.5 per cent, were positive for *C. ulmi*. The log was removed from the cage in October and left on a rack out-of-doors all winter. It was caged again the following spring, and 223 of the 359 beetles which emerged were cultured between June 1 and July 17. Of these, 4, or 1.8 per cent, were positive.

In 1936, eight additional trap-log stations were located at the edge of the known disease area near the stumps of removed diseased trees. At four of these stations *Scolytus multistriatus* entered the logs, and from two of them *Ceratostomella ulmi* was cultured from recently entered beetles (table 1).

In 1937, the galleries were not systematically examined for coremia. However, while the beetle counts were being made, coremia were found in pupal cells and maternal galleries in one of the Pelham Bay Park logs. Half of this log was caged and produced positive beetles.

TABLE 1. RESULTS OF EXAMINING SCOLYTUS MULTISTRIATUS GALLERIES IN TRAP LOGS FOR COREMIA OF CERATOSTOMELLA ULMI; CULTURING RECENTLY ENTERED SPECIMENS OF S. MULTISTRIATUS; AND CULTURING THE EMERGING PROGENY

Location		Year	1. Galleries			2. Recently entered living beetles			3. Emerging progeny of 2		
Town or city	County		Number examined	Number with coremia	Per cent with coremia	Number cultured	Positive		Number cultured	Positive	
							Number	Per cent		Number	Per cent
Armonk	Westchester	1935	1	0	0.0	0			0		
Yonkers	Westchester	1935	1	1	100.0	0	..	...	0	..	...
Pelham	Bronx	1935	1,605	75	4.6	146	9	6.1	0	..	...
Yonkers	Westchester	1936	5	0	0.0	0	..	...	0	..	...
Pelham	Bronx	1936	730	21	2.9	219	60	27.4	48	30	62.5
Mahopac (1)	Putnam	1936	52	0	0.0	12	0	0.0	0	..	...
Mahopac (2)	Putnam	1936	1	0	0.0	0	..	...	0	..	...
Harriman	Orange	1936	52	0	0.0	23	1	4.4	0	..	...
Monroe	Orange	1936	47	2	4.2	22	2	9.1	0	..	...
Pelham	Westchester	1937	few	few	..	0	..	...	111	4	3.6

The data from the Pelham Bay Park station (called Pelham in the table) for 1936 are the most complete. These point to a significant relationship; namely, that not all spore-bearing beetles which enter healthy logs give rise to fungus-infested colonies, but that the few infested colonies may give rise to spore-bearing beetles in numbers larger than those originally entering. Further evidence of a possible "build-up" of *Ceratostomella ulmi* in healthy logs was obtained from data from the logs placed at the collection stations.

COLLECTION STATIONS

In addition to the regular trap-log stations, after 1936 other stations which were called *collection stations* were set up. In 1937 and 1938, a collection station consisted of a group of healthy elm logs, about 4 feet in length and of varying diameters, set up in the form of a "tepee", with their bases resting on the ground in a small circle and their upper ends leaning against one another. In 1939, at many of the stations, the logs were piled horizontally. A complete list of the stations is given in table 3. The four locations in Westchester County were in the area where the disease was generally prevalent. The stations in Putnam and Dutchess Counties were established at known distances from removed diseased trees. The distance from a station to the nearest diseased tree varied from a few feet to nearly 2 miles (table 3).

Two significant types of records were taken from these collection stations: (1) culture data from beetles collected as they alighted on the logs in the course of their normal free activities; and (2) culture data from the progeny of such beetles, obtained by collecting and culturing specimens that emerged from some of the logs which had been brought in and caged. The only field-collected specimens discussed here are those collected at stations where a culture record was also obtained from some of their progeny emerging from logs brought in and caged. At the time the stations were set up, several of the logs at each station were paraffined to retard drying so that they might be used later as a source of beetles for cul-

turing. These logs were left in the field until nearly time for beetle emergence, then brought in, cut into smaller pieces, paraffined, and caged. In the experiments discussed under the heading "Trap Logs", the logs which were caged were selected because coremia of *Ceratostomella ulmi* had been found in the galleries; the logs discussed under "Collection Stations" were chosen at random. At the time the latter were caged, examinations revealed abundant growth of coremia in maternal tunnels and pupal cells in several of the logs.

Table 2 includes all data obtained from 1937 through 1939 where cultural studies were made both of the entering beetles and of the progeny of the brood which developed in the logs at the stations.

TABLE 2. RESULTS OF CULTURING SCOLYTUS MULTISTRIATUS ENTERING HEALTHY ELM WOOD AT COLLECTION STATIONS AND EMERGING FROM THAT WOOD

Location		Beetles				
Town or city	County	Time of collection and culturing	Status of beetles	Number cultured	Number positive	Per cent positive
Yonkers (BTA)	Westchester	{ Spring, summer, '37 Summer, fall, '37	1st brood entering Progeny emerging	483 597	27 79	5.59 13.23
Yonkers (BTF)	Westchester	{ Summer, '37 Spring, '38	2d brood entering Progeny emerging	758 382	7 237	0.93 62.00
Yonkers (BTF)	Westchester	{ Summer, fall, '38 Spring, '39	2d brood entering Progeny emerging	225 348	2 7	0.88 2.05
Ardsey	Westchester	{ Spring, '39 Summer, '39	1st brood entering Progeny emerging	38 59	0 5	0.00 8.47
Tarrytown	Westchester	{ Spring, '39 Summer, '39	1st brood entering Progeny emerging	9 42	1 1	11.10 2.38
Hyde Park	Dutchess	{ Spring, '39 Summer, '39	1st brood entering Progeny emerging	122 71	7 27	5.74 38.01

In 1939 culture records were made of the progeny of beetles which entered logs exposed at several stations where no cultures had been made of the entering beetles. Table 3 includes data obtained in this way from the stations set up that year. The names of the stations which appear also in table 2 are starred in table 3.

TABLE 3. RESULTS OF CULTURING SCOLYTUS MULTISTRIATUS EMERGING FROM HEALTHY ELM WOOD FROM COLLECTION STATIONS, SUMMER OF 1939, 2D BROOD EMERGING

Location		Number of beetles cultured	Number of beetles positive	Per cent of beetles positive	Distance to nearest confirmed tree	
Town or city	County				1938	1939
Yonkers (BTF)	Westchester	157	0	0.00	1400 feet	3000 feet
Yonkers (BTA)	Westchester	95	0	0.00	1800 feet	2000 feet
Ardsey*	Westchester	59	5	8.47	1600 feet	1000 feet
Tarrytown*	Westchester	42	1	2.38	200 feet	3500 feet
Patterson	Putnam	23	0	0.00	1½ miles	1 mile
Schultzeville	Dutchess	218	0	0.00	200 feet	4000 feet
Stanford	Dutchess	76	1	1.31	25 feet	2½ miles
S. Millbrook	Dutchess	3	0	0.00	1 mile	1½ miles
Poughkeepsie	Dutchess	117	2	1.70	4000 feet	2000 feet
Hyde Park*	Dutchess	71	27	38.01	2 feet	1 mile

*See also table 2.

NATURALLY OCCURRING UNINFECTED BEETLE-WOOD

In 1937, in an open field, about one mile from the nearest known diseased tree, a 24-inch elm was found which had been struck by lightning shortly before the first of June. This tree, which was near Washingtonville, in Orange County, was discovered on July 31. Examination and tissue-culturing gave no evidence of infection by *Ceratostomella ulmi*. The branches contained a large number of colonies of *Scolytus multistriatus*. Beetles were both entering and emerging, and were present in all stages. Samples of the wood were brought into the laboratory for beetle emergence. The data obtained are presented in table 4, together with data obtained from other wood as described below.

On August 18, 1938, in Ardsley, Westchester County, a tree which had been killed the preceding year by girdling was found to be heavily infested with *Scolytus multistriatus*, specimens of which were emerging at the time of discovery. This tree was a few feet from a diseased tree which was removed the same day the girdled tree was removed. A portion of the girdled tree was cut up and caged, and beetles emerging were cultured. The data appear in table 4.

TABLE 4. RESULTS OF CULTURING SCOLYTUS MULTISTRIATUS EMERGING FROM FIELD-COLLECTED UNINFECTED WOOD

Location		Type of material	Time of collection	Time of beetle emergence and culturing	Beetles		
Town or city	County				Number cultured	Number positive	Per cent positive
Washingtonville	Orange	Lightning-struck	Aug. 1937	Aug. 1937	559	12	2.15
Ardsley	Westchester	Girdled tree	Aug. 1938	Aug. 1938	202	34	16.83
Ghent	Columbia	Lightning-struck	Mar. 1939	May-June, 1939	2	0	0.00
Tivoli	Dutchess	Dead limb	Mar. 1939	May-June, 1939	120	0	0.00
Sharon Station	Dutchess	Dead tree	Mar. 1939	May-June, 1939	98	0	0.00
Poughkeepsie (1)	Dutchess	Windfall	Mar. 1939	May-June, 1939	19	0	0.00
Poughkeepsie (2)	Dutchess	Broken limb	Mar. 1939	May-June, 1939	37	4	10.81
Warwick	Orange	Windfall	Mar. 1939	May-June, 1939	107	0	0.00
Stony Ford	Orange	Broken limb	Mar. 1939	May-June, 1939	66	0	0.00
Little Britain	Orange	Dead tree	Mar. 1939	May-June, 1939	85	6	7.06
Goshen (1)	Orange	Broken limb	Mar. 1939	May-June, 1939	71	1	1.41
Goshen (2)	Orange	Uncertain*	Mar. 1939	May-June, 1939	71	18	25.35
Edenville	Orange	Dead tree	Mar. 1939	May-June, 1939	78	1	1.28

*Material brought in by a field worker and was accompanied by no description of the exact source.

During the month of March in 1939, wood containing overwintering larvae of *Scolytus multistriatus* was collected at several points in the disease area, but without reference to the locations of known diseased trees. The distances to known diseased trees were determined later. The wood came from such material as broken limbs, trees which had been blown down, and trees dead from causes other than the Dutch elm disease. The wood was examined for discoloration which might indicate origin in a diseased tree. If it came from trees which were still partly alive, the living portions were also examined. If any streaking was found, tissue cultures were made. In no instance was *Ceratostomella ulmi* obtained, and it was assumed that none of the wood used was from infected trees. The pieces of wood generally ranged from 4 to 6 inches in diameter. The ends were paraffined and

the wood was stored out-of-doors. On May 8, the material was caged. The results of culturing the emerging beetles are given in table 4.

The locations from which the wood produced no positive beetles varied in distance from $3\frac{1}{2}$ miles to 20 miles from the nearest known diseased tree of the previous year. The sites from which *Ceratostomella ulmi* was obtained were located from a few feet to 2 miles from the nearest confirmed tree of the previous year.

WOODPILES

On August 11, 1938, a considerable amount of elm wood was found in a pile of stovewood on a farm about five miles east of Poughkeepsie. Many pieces of this wood contained larvae and pupae of *Scolytus multistriatus*. On the same day, examination of another pile at Hyde Park revealed similar conditions. The Poughkeepsie woodpile was $1\frac{1}{2}$ miles from the nearest diseased tree found in 1938. The Hyde Park woodpile was about 500 feet from the nearest confirmed tree of 1938. Pieces from each pile were brought in and caged separately. The data obtained from the cages are presented in table 5.

TABLE 5. RESULTS OF CULTURING SCOLYTUS MULTISTRIATUS EMERGING FROM WOOD TAKEN FROM WOODPILES IN AUGUST, 1938

Location		Beetles		
Town or city	County	Number cultured	Number positive	Per cent positive
Poughkeepsie	Dutchess	144	1	0.69
Hyde Park	Dutchess	130	0	0.00

The two most common farm methods of storing stovewood are piling it in a more or less open shed and piling it out-of-doors. Experiments were made to determine the relative safety of these two methods of storage with respect to the survival of *Ceratostomella ulmi* and the emergence of beetles carrying the fungus. The experiments involved both diseased wood containing *Scolytus multistriatus* and healthy wood in which spore-bearing beetles had been allowed to breed. In order that normal conditions would obtain, the ends of the logs were not paraffined.

Heavily discolored, beetle-infested, diseased wood was cut into lengths of 15 to 18 inches and distributed among three locations in Orange County. At each location, two piles were made: one inside of a shed, supported off the ground by the lower logs or other supports, and the other outside, piled closely on the ground beside the shed.

The healthy wood was cut into four-foot lengths and stored in a cellar for 18 days, after which it was cut into 15- to 18-inch lengths and caged in the greenhouse with beetles which had been artificially infested with spores of the fungus. After 9 days the logs were taken from the cages and separated into 2 lots. One lot was piled on the wooden floor of a shed at Yonkers and the other was piled outside against the north side of the shed.

In both series of experiments, the wood was left under the described conditions for five or six weeks. It was then brought to the laboratory and caged. The cages of diseased wood were kept out-of-doors on racks

in a large, wire-screen cage. The healthy wood was placed in cages in the greenhouse. Data from these experiments are presented in table 6.

TABLE 6. RESULTS OF CULTURING *SCOLYTUS MULTISTRIATUS* EMERGING FROM SMALL LOGS PILED AS STOVEWOOD, SUMMER, 1939

Location	Description of material	Conditions of storage	Emerging beetles		
			Number cultured	Number positive	Per cent positive
Florida, New York	Field-collected diseased wood containing beetles	(a) In shed	99	6	6.1
		(b) Outside shed in shade	119	5	4.2
Pine Island	Field-collected diseased wood containing beetles	(a) In shed	135	13	9.6
		(b) Outside shed on west side in sun among weeds	107	18	16.8
Little York (near Pine Island)	Field-collected diseased wood containing beetles	(a) In shed	47	2	4.3
		(b) Outside shed on east side in sun	38	0	0.0
Totals	Field-collected diseased wood containing beetles	(a) In sheds	281	21	7.5
		(b) Outside sheds	264	23	8.7
Yonkers (BTF)	Healthy wood entered by fungus-infested beetles	(a) In shed	103	20	19.4
		(b) Outside shed on north side	115	16	13.9

It is noted that healthy wood entered by fungus-infested beetles produced a higher percentage of positive specimens than did diseased wood. It was concluded that the storage of untreated, beetle-infested wood out-of-doors or in an ordinary barn or woodshed is unsafe, whether or not the wood is diseased.

RELATION OF BEETLE-INFESTED UNINFESTED WOOD TO DISEASED TREES

When trees in the field are examined at random, feeding by *Scolytus multistriatus* in the twig crotches of living elms appears rather erratic. It was pointed out by Donald L. Collins (1938) that trees adjacent to wood which is either attracting or producing beetles, and trees containing such wood are most likely to be visited for feeding. Since 1938, additional data from laboratory and field experiments and from general observations have indicated that the wood from which beetles are emerging is the more important, since they feed heavily on near-by trees. Wolfenbarger and Buchanan (1939) and Fransen (1939) have made similar observations.

Of the 304 trees confirmed as diseased in the counties of Ulster, Columbia, and Dutchess in 1939, 217 were inspected by members of the laboratory staff to determine the extent of beetle-feeding and the year of infection. The vicinity of each tree was scouted for sources of *Scolytus multistriatus*, and maps were drawn of each site. The number of trees recorded as having become infected during the spring and summer of 1939 was 127.

The approximate time of beetle emergence from a given source, the approximate age of feeding wounds, and the time of infection of diseased trees could usually be determined within reasonable limits. It was ordinarily possible, therefore, to ascertain whether the wounds on a given diseased tree were made by beetles emerging from near-by wood at the proper time to cause that specific infection. In the vicinity of 65 of the 127 trees, a definite beetle source, from which beetles had emerged in the

spring or early summer of 1939, was found within 700 feet. The sources of beetles consisted of dead branches, broken branches (both those still hanging in the tree and those which had fallen to the ground), felled trees, trees blown over by the wind, and woodpiles. In several instances, the source of beetles was located in the diseased tree itself. Sources of this type were in parts of the tree which had broken off or had died before the time of infection, and which had attracted beetles whose progeny fed upon and presumably inoculated the tree. Nearly half of the 65 trees in question had beetle sources of the types described within 25 feet. Figures relative to the diseased trees and beetle sources are presented in table 7.

TABLE 7. LOCATIONS OF SOURCES OF *SCOLYTUS MULTISTRIATUS* IN UNINFECTED WOOD WITH REFERENCE TO LOCATIONS OF DISEASED TREES IN 1939

Description of diseased tree	Number of trees within specified distances of beetle sources in uninfected wood			
	650 feet	500 feet	100 feet	In or under tree or within 25 feet
Single.....	27	26	18	16
In groups of 2 or more.....	38	36	23	13
Total.....	65	62	41	29

Of the remaining 62 trees, not included in table 7, which were inspected and judged to constitute 1939 infections, all but two occurred singly; that is, they were not associated with other diseased trees. These 62 trees are considered separately because they were not definitely related to beetle material from which it could be determined that emergence had taken place in the spring of 1939. Nearly all of them, however, were in swamps or in other unfavorable situations, and usually there was a considerable amount of dead wood in the vicinity. Much of this dead wood was inaccessible for close observation, but in most instances evidence of the presence of *Scolytus multistriatus* was found.

There were a few sites where no sources of *Scolytus multistriatus* could be found in the immediate vicinity of the diseased tree, but where there were sources of *Hylurgopinus rufipes* within 500 feet. *Scolytus sulcatus* LeC. was found not infrequently breeding in or near diseased trees.

With the exception of one group of 2 trees, whenever 2 or more diseased trees were found associated with one another, a source of *Scolytus multistriatus* was definitely established. Thus, a total of 40 trees with 1939 infections were found in groups of 2 to 7 trees, and, as may be noted in table 7, 38 of the 40 trees were definitely associated with a source of beetles. From these observations, it appeared that wherever a number of trees were inoculated by beetles from the same source, that source was usually large and easily found.

An example of what can happen when beetles are allowed to build up a heavy population in a limited area was seen in a swamp near Kingston during March, 1940. A low area adjacent to a small pond had a large elm population including trees of all diameters up to about 25 inches. The area was roughly 500 feet long by 300 feet wide. Sometime prior to 1939 the area had been flooded, resulting in the death of many trees, which became infested by *Scolytus multistriatus*. Emergence in large numbers

from these trees first took place in the spring of 1939, and the beetles fed heavily on the adjacent trees during that period. Nearly all of the living trees were sampled and 33 were confirmed. No confirmed tree was more than 100 feet distant from a beetle source, from which beetles had emerged in the spring of 1939, and all of the infections had occurred during that period.

In the instances cited usually no opportunity was offered for culturing the suspected beetles, since they had fed and disappeared by the time the diseased trees were seen and removed. Such an opportunity occurred in one case, however, when a broken branch on an uninfected tree near Poughkeepsie was found to contain colonies of *Scolytus multistriatus* in March, 1939 (Poughkeepsie (2) in table 4). A section of the limb was brought in, and from this section 37 beetles, which emerged in May and June, were cultured. Of these, 4, or 10.8 per cent, were positive. In the meantime, the rest of this limb, which had been left as it was found, was producing beetles, as evidenced by subsequent examination. During the summer, a tree about 50 feet distant became infected with the Dutch elm disease. The nearest confirmed tree the previous season had been a mile away. The circumstances inevitably suggest the cause-and-effect relationship assumed with respect to the trees mentioned above as being associated with known beetle sources.

SUMMARY AND CONCLUSIONS

As high as 15 per cent of the specimens of *Scolytus multistriatus* collected in the field in southeastern New York State were found, by culturing, to be carrying the Dutch elm disease pathogen *Cerastostomella ulmi*. When cultured directly after emerging from diseased wood, as high as 100 per cent of the beetles were positive for *C. ulmi*, but usually they averaged considerably less than 50.

When beetles were artificially infested with spores and allowed to enter healthy wood, as high as 74 per cent of their progeny emerged carrying spores of *Cerastostomella ulmi*. Healthy cut logs exposed to normal beetle attack in the field produced as high as 62 per cent of positive beetles in the progeny of parents which probably averaged much lower when entering. Pieces of uninfected beetle-wood found in the field produced as high as 25 per cent of positive beetles.

Uninfected elm wood in farmers' woodpiles also produced positive beetles. Diseased wood cut in short lengths and piled produced as high as 16 per cent of positive beetles when stored out-of-doors and as high as 9 per cent when stored in sheds. Healthy wood cut and stored in a similar way, but subjected to entry by spore-bearing beetles, produced 14 per cent of positive beetles when stored out-of-doors and 19 per cent when stored in a shed.

In 1939, in the counties of Ulster, Columbia, and Dutchess, that is, in the peripheral regions of the disease area, 217 of the 304 confirmed trees were inspected. Of these, 127 were recorded as having become infected in 1939. In the vicinity of 65 of these trees, uninfected wood which had produced *Scolytus multistriatus* in the spring or early summer of 1939 was discovered. In these instances there appeared to be a definite correlation of beetle emergence and beetle feeding with the probable time of infection.

This led to the inference that the disease pathogen was communicated to these trees by beetles which had emerged from uninfected wood. Whether this inference is justified in every instance, it was shown that uninfected wood can, and often does, produce beetles which carry inoculum. Dead or dying elm wood of whatever origin, if suitable for the breeding of *Scolytus multistriatus*, is therefore a potential source of inoculum from which the Dutch elm disease pathogen may be spread by emerging beetles. Since the beetles can carry the fungus into uninfected wood, and their progeny can carry it out, such wood serves as a reservoir for continuing local dissemination of the disease organism. It may also act as a bridge for the transfer of the fungus from the disease area to regions where the disease does not occur.

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